Consumer to Creator: How Households Buy Furniture to Inform Design and Fabrication interfaces

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ABSTRACT

Emerging technologies for digital design and fabrication let people participate in the making of objects that were previously dominated by professional designers. A growing body of work in HCI provides understanding in the activities of designing and making by novices and in maker communities. However, we know little about how casual users might employ these technologies with the goal of having an object in their home that satisfies a need. We present a long-term qualitative study in which we followed 16 households during a purchasing process of furniture items for their homes. We looked into how families discover what they need, find solutions, realize a solution in their house and put it to use. The results provide insights into their design activities and workflow and we identify two distinct stages: understanding needs and prototyping a solution. Based on the findings, we discuss the social practice of acquiring and appropriating furniture in the home and within families, and identify design opportunities for digital design and fabrication to support people as they create the objects they need, want and desire.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): Graphical User Interfaces

Author Keywords

fabrication; design; purchase; furniture; qualitative study

INTRODUCTION

People select furniture items through careful considerations. When they buy a chair for their desk, they are concerned with ergonomics and comfort and tend to test the real product in a store. When they buy a new rug to decorate a room, they explore styles to match their interior. Also, as furniture is shared within a family, the purchasing process has multiple stakeholders. To make decisions that satisfy their requirements, people employ various practices to discover what they need, find possible solutions and prototype candidate solutions in their house. Whereas people traditionally relied on information from manufacturers, they are increasingly relying on user generated contents. Although most furniture used to be acquired offline, the current trend is online shopping and requires new ways of understanding the fit of a solution. Users have natural hesitation to purchase a product that they have not yet experienced in person [31], and this is the case with online purchase, customization and perhaps with digital fabrication.

We see the practice of buying durable things as *variant design* [29], and see people as *everyday designers* [46] who want to acquire a product that satisfies their needs. With such a 'design lens', we aim to gain insights in the practice of buying items [47] to inform the practice of customizing items and as a means to reflect on future fabrication interfaces for makers or casual users. We are interested in how people go through such a decision-making processes with an emphasis on how they figure out what they need and how they find or prototype solutions in and for their homes. Although understanding the purchase decision-making process is the core of consumer behavior research [3] and mass customization toolkits [41, 45], they do not look into the prototyping activities users perform in their homes. Current HCI research into fabrication interfaces [14, 33] has a focus on modeling 3D geometry. However, the process that takes place before configuring or modeling the solution has not been fully explored. This gap in the literature is the driving force of this paper.

We build on the rich tradition of studies in people's houses [8, 20, 30, 46, 51] to gain a thorough understanding into the social practice [34, 38] of appropriating new furniture items. We captured the entire furniture purchasing process of 16 households through a diary study complemented with two house visit interviews: before purchase, right after purchase, and a telephone interview two months after the item was put into use. Insights from this study extend the understanding of *design-in-use* [46] with an understanding of the 'design process' regarding introducing new items. Our study indicates that families start with a breadth-first top down mutual exploration of the solution and problem space, followed by a depth-first testing and prototyping stage. Our results contribute to prior studies regarding expertise in design [9].

This paper makes two contributions. First, it provides empirical findings regarding the households' furniture purchasing cycle, and shows the key activities and sources observed in each stage. Next, we documented social practices as high-level insights, and suggest several design opportunities for non-professional fabrication tools derived from real-life needs and behaviors.

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RELATED WORK

The availability of low-cost fabrication devices has motivated research into digital design and fabrication technologies for non-professionals. Several studies [14, 22, 33, 48] aim to support users in their creation of 3D CAD models and in the generation of fabrication-ready 3D models based on 2D sketch input or from clay models. Advances in real-time simulation provide users with interactive feedback and suggestions on aspects such as the manufacturability [33] and the structural integrity [42] and allow users to embed professional engineering and aesthetic knowledge into the design tool. Other research projects consider the object within the context of use and let users engage in design with existing objects [14, 23, 49] to make objects that fit other objects or to situate the modeling task within the intended use environment. Another body of work looks into DIY enthusiasts [32] and maker communities that make use of these tools. These studies reveal how people engage in such activities and are motivated by enjoyment, skill building, creativity and a feeling of accomplishment [21]. Online and offline communities of practice [16] are instrumental for information exchange, inspiration and education.

Whereas for these communities the creativity and crafts are the main driver, we are interested in the application of fabrication as an alternative for purchasing readily available objects. Hudson [18] studied the workflow of casual users that use a public 3D printing center with the goal of making objects. Typically, these users are new to designing objects and have trouble relating interdependencies of design decisions with the fabricated objects. A recent study into how casual users prototype by hand in a design session [5] reveals similar barriers attributed to the relationship between sketches (shape) and fabrication challenges (process). Also, this study revealed that people face difficulties explaining sketches and fabrication methods to each-other. These indicate differences between expert amateurs [21] who use digital fabrication as a goal and casual users for whom it is a means, and the result is the goal.

Shewbridge et al. [36] placed an imaginary 3D printer in twelve households. In a longitudinal study, they asked people to document what they would do with it. Most objects that participants wanted to fabricate were duplications: more of the same, sometimes improved; only seldom did they talk about new objects. Those results indicate the mundane customization scenarios that Pahl and Beitz [29] call variant design, a unique product within a known principle solution. Decisions such as choosing a color for a wall [50] are preceded by a design process that begins with a vague notion that considers nearby furniture and perceptual attributes regarding color tones. Several sources are used for inspiration and information such as magazines and display homes. In this paper we are interested in understanding the process of casual users and how they prototype and make decisions in their home.

We build on ethnographic studies of people's homes that indicate differences between design for professionals and for use in households, as domestic life is not characterized by a shared objective but by a diverse range of contrasting interests [8]. Wakkary et al. [46] show how object use evolves over time in conjunction with need satisfaction and call this *design-in-use*. Families test out new systems by concurrently adapting their routines to the system and adapting the system to the daily routine [11]. Likewise, Woo and Lim [51] studied how households program rules for IoT smart home automation and identified several stages in how these devices are put to use. In a *motivation* stage, which precedes a programming stage, participants identify a need. After programming and implementation, stages follows a *use-through-routine* stage in which the rules are tested in daily routines and adapted as insight in their routines grows. These studies reveal the rich and iterative process of how users appropriate objects in their daily lives [12]. The studies also show the roles of family members; for instance, the programmer is not always the user. Given these insights, we expect to find similar rich and informal methods when we follow households as they select new objects in their homes.

From the field of Consumer Behavior, we learn that decision making is shared within families and between spouses [39, 40]. Similar to results found in the ethnographic studies, family members take various roles in the process that leads to a purchase. Roles include those of information gatherers, influencers, decision makers and purchasers [37]. A key theory is the consumer decision-making model of Engel, Kollat and Blackwell (EKB) [3]. This model assumes that people who purchase items go through a fixed sequence of distinct stages consisting of 1) problem recognition, 2) information search, 3) evaluation of alternatives, 4) purchase and 5) post-purchase evaluation. In the three stages leading up to the purchase, *consumers* make use of a variety of information and inspiration sources both external (e.g. visiting shops and searching websites) and internal (e.g. prior experience, advice from friends and relatives). Although it has been criticized taking a utilitarian perspective [3], too rational and linear, the EKB model still mapped well to our pre-purchase stages and the different types of information sources we found in our study.

People have trouble understanding their needs, finding products that suit those needs or configuring a customized product [31]. Therefore, recommender websites provide various means to let people compare alternatives. Likewise, mass customization websites support iterations and guide users through a configuration process. A combination of design parameters results in product performance that matches a user need [41]. Hence, these toolkits try to match the user's skill [10] and repartition the design task to present the user-need parameters to the users [45]. We identify the information needs for buying objects and how people work together. We argue that buying objects provides insight into how people would make objects. It is not about making a creative or innovative design, but coming up with a solution for the home that fulfills a need and is appropriate for the situation.

THE STUDY

The EKB model [3] provides a high-level overview of how people acquire goods from a vendor's perspective. However, it provides little insight into the actual practices that are important for future design and fabrication interfaces, e.g. how people test potential solutions in their houses and how they share inspiration among family members. Hence, we con-

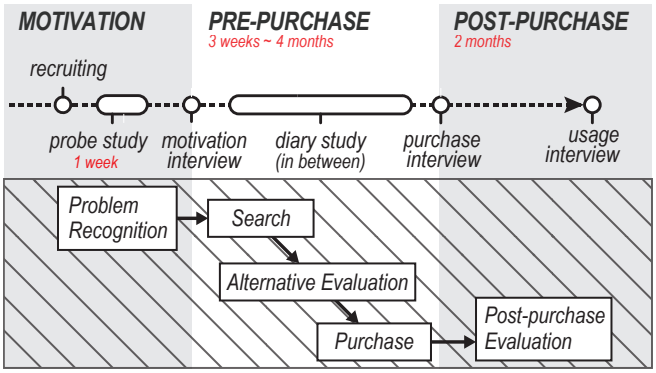

Figure 1. The research process consisted of three phases (corresponding to the EKB model): motivation, pre-purchase, and post-purchase. We started with a probe study and motivation interview, followed by a diary study until the moment of purchase. Directly followed by a purchasing interview, and a post-purchase interview about one-month later.

ducted a long-term qualitative study with 16 households. Two field interviews in the participant's homes enabled them to refer to their furniture and show their routines [4] and a diary study let participants log events related to their furniture decision making. A follow-up interview two months after the purchase was conducted to let participants reflect on their purchases. The entire study was held from February to August in 2016, and on average it took participants 105 days from the first *motivation* interview to the *purchase* interview (Figure 1).

Item Category Selection

We selected furniture as a product category for this study because of three reasons. First, furniture items are durable goods and purchase decisions take considerable effort compared to commodities that are routinely purchased or fast fashion items that are bought in the spur of the moment. Hence, we expect households to engage in an extensive selection process prior to purchase. Second, furniture items have to meet a variety of requirements. They have to match the existing interior, and have to fit within the available space as well as have ergonomic and comfort considerations. Finally, furniture items are typically shared among family members, which means that the purchasing process has multiple stakeholders. For these reasons, we assume that selecting furniture is situated and collaborative and that users go through an elaborate purchasing process. In addition, we see digital fabrication of personalized and customized furniture as a feasible scenario in the near future which encourages further investigation (e.g. Opendesk [28]).

Participants

The sixteen households had 29 members in total, all from a metropolitan area in South Korea. The main criteria for participation was who already had a plan to purchase a furniture item. We recruited participants through flyers posted in apartments, social media, and online communities of housewives. The participants' ages ranged from 19-48 for main household members and 4-18 for their offspring. Their occupations varied, but all were middle class, as shown in Table 1. We selected households of four types: single male, single female, young couples without children and couples with children. The

Type A. Single Male		
A1	Ph.D student [Industrial Design] (29)	Chair ($80)
A2	Undergraduate student [Biomolecular Engineering] (21)	Wardrobe ($90)
A3	R&D office worker (27)	Side desk ($80)
A4	Undergraduate student [Undeclared Major] (19)	Rug ($15)
Type B. Single Female		
B1	UX designer (25)	Rug ($15)
B2	Researcher (25)	Rug ($20)
B3	Ph.D student [Chemical Engineering] (25)	Desk ($40), Chair ($45)
B4	Ph.D student [Aerospace Engineering] (27)	Rug ($50)
Type C. Couples without Children		
C1	H: Post-doc [Biology] (32) / W: Ph.D [Biology] (26)	Side table ($30), Stool ($30)
C2	H: Company Employee (27) / W: Ph.D student [Chemistry] (28)	Table ($155), 2 Chairs ($20)
C3	H: Ph.D student [Computer Science] (26) / W: Researcher (26)	Sofa ($900)
C4	H: Ph.D student [Mechanical Engineering] (27) / W: Housewife (27)	2 Chairs($130), Cabinet ($40)
Type D. Couples with Children		
D1	H: Company Employee (36) / W: Part-time worker (41) / D (6) / S (4)	Shelves ($20)
D2	H: Salesman (34) / W: Housewive (33) / S (6)	Hanger ($80)
D3	H: Professor (54) / W: Housewive (48) / D1 [Mechanical Equipment Enginnering] (23) / D2 (18)	4 Chairs ($240)
D4	H: Company Employee (41) / W: Housewife (38) / D (16)	2 Stools ($130)

Table 1. The demographic information of the participants (H:husband, W:wife, S:son, D:daughter), and furnitures they bought including cost.

single households, except one, are living in semi-furnished apartments equipped with basic furniture such as a bed, desk and closet. Households in type C are newlyweds, who recently moved into new houses, less than a year ago, and were in the middle of the process of buying new interior items. All the families in type D had been living together for more than 6 years and had fully furnished homes. None of them had professional knowledge of making furniture; only two people out of 29 had some experience as makers (in fabricating wooden furniture) and could be considered as expert amateurs [21].

Research Process

We followed a process similar to that used in related studies [19, 51] and we planned for three stages. The first is problem recognition, which took place prior to the recruitment; the first intake interview was conducted to understand their *motivation* to buy an item. The second stage consisted of the *pre-purchase* and concluded with the moment of purchase and a second interview. Two months after the purchase we conducted a chat-based interview to let the participants evaluate their purchase in the after purchase use-stage (Figure 1).

The goal of the ***motivation*** phase was twofold: to gain a thorough understanding of participants' living situations and their motivation to buy new furniture. We sensitized participants with a probe package [26, 44], especially for the following *motivation* interview. The probe consisted of worksheets, various tools and furniture stickers selected from interior magazines. Worksheets were divided over 4 days, and each day

the participants were asked to reflect on their houses, existing furniture and previous experience with those by drawing a floor-plan or making a collage. We visited the participants' homes, when they finished the probe, and conducted the *motivation* interview with all family members. We started the interview by asking for background information, residential situation, house structure and history of other furniture at home to understand the differences between the diverse characteristics of each family member. Then, to gain insight into their process and needs, we continued with questions about the item they planned to buy, their motivations and activities they had already performed for the purchase. The interview took about 40 minutes per household.

The second phase is ***pre-purchasing***. In this phase, participants kept a diary to record their purchase-related activities or considerations until they bought the actual product in a popular social messaging application [27]. We assumed that the impact of the diary study on the process would be minimal, but inevitable, because all participants frequently used a smartphone and this application was deeply rooted in their daily activities from communicating with relatives and friends to ordering food and calling taxis. Because we provided a digital messaging application as a logging tool, the participants were able to easily take and upload photos at any location. In addition, as all household members shared one chat room, we could easily capture the collaborative process among households. As soon as they purchased the product, we scheduled the *purchasing* interview to understand the entire process that participants went through when buying their item. The interview followed a semi-structured format, allowing the interviewer to probe further about each diary entry; also, participants were able to show and tell about their purchase in their houses. The interview took between 20-60 minutes.

The final phase is ***post-purchasing***, in which the users use the furniture item. About two months after the purchase, we conducted a chat-interview to let participants reflect on usage and asked how they used the product, their satisfaction level, the points they missed in the previous purchase and needs for future items.

Data Analysis

The qualitative data was stored and managed using the data management software NVivo. The results from the diary study, and the transcribed narratives from two interviews, were used for the analysis procedure. Our approach consisted of three steps, similar to those in [19]: open coding, axial coding and iterative quantitative analysis. The ***open coding*** was done with results from the nine households that finished first. This coding aimed at identifying the key structure of the purchasing process, without any assumptions. This process was done five times with identical comments for different aspects: activities, requirements, sources, barriers and enablers and roles. Using ***axial coding***, we categorized the initial set of phenomena described by open codes. Open codes were grouped into categories that were subsequently analyzed in terms of similar objectives. This resulted in a set of four stages of the design workflow, and relevant categories for activities, sources, and barriers for each stage. Then, all the quotations from 16 households were classified as being primarily related to one among the categories of the four stages. This process was independently conducted by the first and one additional researcher (Interrater agreement K=.81). Quotes for which no agreement was attained were excluded from the analysis. Finally, a furniture 'design' workflow that can be applied to all participants was discovered, and key activities, key sources and needs were identified accordingly.

DESIGN WORKFLOW

As shown in Table 1, participating households bought various types of furniture. They spent a considerable amount of time understanding their needs and exploring solutions available on the market. In total, it took 14-83 days from starting motivation to settling on a single appropriate item. Then, a second stage followed in which they employed various activities to test fit the item in their houses. All households iterated a few times before making the actual purchase, and this second process took from 1-27 days. After using it for 30-50 days, they indicated several issues with the items in actual daily use, even though they selected the items with careful considerations. We framed these procedures as a product design process [7] with alternating stages of diverging and converging. The workflow consists of four stages: *motivation*, *exploration*, *realization*, and *use*, as shown in Figure 2. These stages were observed in all 16 households, but the details varied based on the purchase motivation, familiarity with the item and household type; and are detailed below.

Motivation

The households displayed a wide variety of *motivations* to understand that they needed a new furniture item in their houses. Some participants were motivated by uncomfortable experiences using their existing furniture. For example, B3 decided to buy a new desk to replace her previous one, which was uncomfortable to use with her computer. Some participants were attached to their furniture and tried to upgrade their existing items instead of replacing them, as in an *appropriation* process [46]. C4 mentioned, *"The sofa we bought at IKEA was originally meant for two purposes: as kid's bed and a small sofa. But was not that comfortable compared to other sofas. So, we decided to buy extra cushions for it."*

Two newly married couples, who recently moved into new apartments, had to buy basic items such as a sofa, bed, dining table and chairs for the first time. Several families (C1, C2, C4), bought *additional furniture* to solve daily functional issues related to their lifestyle. D2 mentioned, *"My husband always leaves his clothes on the bed without arranging them because there is not enough space in our wardrobes. So, we decided to buy one more clothes hangers."* On the other hand, some families were eager to have extra items to decorate their houses for aesthetic purposes. D1 commented, *"I thought the plant named Tillandsia would make the room interior beautiful. I want to put that plant on a new wall shelf to decorate the living room."* All households came up with a certain price range in the *motivation* stage.

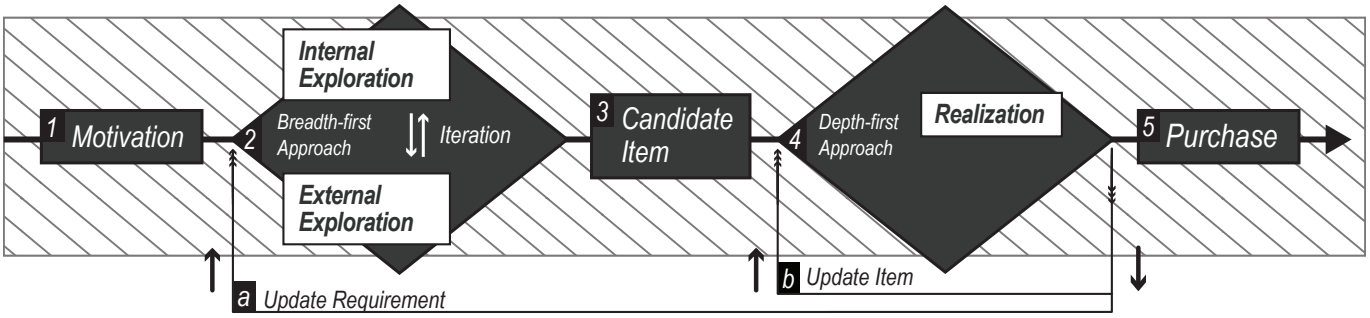

Figure 2. The purchase workflow observed in all households. This diagram corresponds to the double diamond design process.

Exploration

With a clearly identified need for a new furniture item, participants engaged in an analysis stage. They explored the solution space to find trends and products available in the market (external analysis), and the problem space to gain insights into their requirements (internal analysis). These spaces co-evolved [13] during the process. C4, for instance, had the requirement of matching material with their wooden table and used 'wood' as a keyword to search online for chairs. However, when participants couldn't find solutions that satisfied a requirement, they went back to the external sources and got inspirations from experts or other users and updated their requirements. For instance, C2 wife stated in a diary entry that she had difficulty finding a proper size table to fit in her house that was also comfortable to use. So she searched on an online community of housewives and realized that other people had solved this issue with an extendable table.

External Analysis: Understanding the Solution Space

The external analysis consisted of an online search that was mostly focused on the styling of items. Participants visited both online furniture stores as well as blogs with photos made by users. All households except 2 participants used their mobile phones to collect favorite items as images. When they encountered favorite furniture in department stores (C4), restaurants (D2) or friends' houses (D3), they took pictures with their phones to add to their collections. During the interview, D1 wife showed various furniture and interior images with her mobile phone that were downloaded from an online mall and community, *"When I found an image I liked, I downloaded it on the mobile phone. As time goes by, more images piled up in my album."*

Compared to their knowledge of commodities and fashion items, participants had little experience in buying furniture. Therefore, they extensively utilized sources such as online marketplaces and search engines. Through exposure [43], people gained insight into features and styling. In the diary study, D1 wife revealed she had visited an online mall and looked at all the images in the shelf section to learn the various design possibilities. Typically, participants review large quantities of items and, during this process, some develop a personal taste. C1 husband stated, *"The first time, I reviewed as many images as possible, but by excluding images I didn't like, I discovered my taste."* Only two out of 16 households visited offline stores to see various types of furniture.

Acquiring fashionable or popular items was important for 14 households. Some households obtained *trend* data from browsing through curated collections or luxury websites. B2 pointed out in the diary, *"Rather than the normal online marketplace, I visited curated shopping sites in order to check items evaluated by a professional merchandise planner."* Other participants used crowds to obtain a sense for popular items. For example, B4 checked the best seller items in a well-known online mall by using the ranking filter function.

We discovered that user-generated content had a large impact on all the households as they explored how other people deal with similar design requirements and motivations. All households collected user-made photos of the *product-in-use* to see how it was used in real life situations. For example, D2 wife found how other users with similar houses decorated their rooms through pictures in an online community or on blogs, and downloaded all the images to copy their style. Single households mentioned that they were inspired by people in similar residential situations and also had to decorate a semi-furnished room with a small amount of money.

When participants had no experience using a piece of furniture, *online user reviews* also worked as a source of experiential information. Sometimes, newly married couples got information on parents' experiences for basic furniture, such as sofas. C2 mentioned that their parent's experiences were helpful because they had already experienced four different sofa designs. In addition, some participants spent lots of time studying *expert knowledge* of a certain product. When some households had a specific style they liked, such as 'modern', they visited websites of brands selling that style to check how professional designers design matching furniture. B3 and D4, on the other hand, were planning to buy a chair and the ergonomics were their main concern. So they educated themselves with information online to learn about ergonomic posture and height.

Internal Exploration: Understanding the Problem Space

While exploring product aesthetics from various external sources, participants also gained insight in their design requirements. Price was an important requirement but was already determined during the motivation stage. Other requirements were implicitly made and shared, and none of the participants

House	House atmosphere	- Color that represents same feeling as house interior - Matching color with current house wall or floor
	House layout	- Proper item style that harmonizes with current layout - Proper features that emphasizes spatial efficiency - Proper size for spatial efficiency - Proper size that fits in certain space
Nearby Items	Pair-using furniture	- Matching color / material with pair furniture - Similar style / design with pair furniture - Relatively proper size with pair furniture
	Together-use personal items	- Proper features for personal items - Proper sizes that fits to personal items
Users	Ergonomic uses	- Proper features for ergonomic use - Proper sizes for ergonomic use
	Functional uses	- Features from previous usage experience - Features for future usage plan

Table 2. The list of design requirements related to the house, items and users, which are implicitly made in the internal exploration.

made a list. The relative weight of requirements surfaced during the interviews but was also not made explicit. For instance, A3 regarded 'size' that fits his house as a primary requirement for his desk, and A2 considered 'number of shelves' as the most important factor for his wardrobe. Some households attached great importance to aesthetic aspects, for example, A4 stated that 'ethnic style' was essential. For ergonomic products such as chairs, soft constraints such as comfortability or healthiness were crucial for both B3 and C4.

A number of requirements concerned the *layout and interior of their houses*. All participants expressed the desire to find materials that match with their current interior and tended to express ideal color through 'adjectives' that demonstrate the feeling of their current house [50]. For example, C4 stated, *"As our bedroom atmosphere is cozy, as you can see, steel is not a good option. The material should be warm-colored."* For participants who lived in small houses, size and space-saving features were important requirements. B3 mentioned, *"As there is a large window in front of the future desk place, there should be no desk-shelves in the front of the window. Also, I need to access the window easily to open it and to put my plants on the windowsill. So the desk should not cross the window outline."*

Participants defined dimensions through several activities. B1 drew a floor plan and brainstormed the best size by drawing various sizes and positions of the desk on the floor (Figure 3a). Two households did physical prototyping activities by using other objects. C1 husband positioned a side table near the sofa to test and check the appropriate height and color. He re-enacted their activities during the interview, as shown in Figure 3b. Also, people defined the maximum length of the item by measuring the available space and defined the minimum length by measuring the size of the object with a ruler.

Existing *pair-use items* provided several constraints for the planned new items. C1 wanted to match the color of the side table with their sofa, and B3 mentioned that she wanted to match the color tone of the wood between the shelves and the desk. For B2, nearby furniture acted as a size constraint. She stated, *"The size of the rug should not pass the bed nor the cabinet. If it does, it might look like a floor cover."* The dimensions of items such as shelves and tabletop surfaces directly relate to the size of other items. For instance, A3 set the minimum size of the desk with the width of his electronic piano, which is needed for music work. D1 wanted to define a proper space for the shelves so that they could place their tissue boxes on it.

Other requirements originated from *comfort and usage patterns*. Several people indicated the importance of ergonomics. C2 tried to estimate a comfortable height for a new table when used with their existing stool. So, the wife sat on the stool and estimated the proper height by moving her hands up and down. C1 wanted to estimate a proper height for a new side table when sitting on their low-height sofa. They measured the height of the sofa with a flexible ruler and kept that as a reference. In the case of other households, who bought furniture for additional functional purposes, participants tried to find proper features or sizes by imagining future use. For example, C4 wife mentioned, *"We currently put our hair dryer on the floor. But we want to improve this. So we need new shelves to put towels and our hair dryer."* In case they replaced old items with new ones, they obtained requirements from their own experience of previous furniture. For instance, the child of D2 family once got injured because the TV cabinet had sharp corners. Hence, safety and sharp edges were their main considerations for the next purchase.

Realization

When households started to frequently discuss a single item, they started *realizing* a solution in their houses. In this stage, they switched to a depth-first search and evaluated items through various prototyping activities and by getting advice from others. However, if that object did not fully satisfy their requirements, they iterated with a new candidate object (Figure 2b) While they were making iterations, they further detailed their design requirements and tastes.

Finding alternative candidate items (Figure 2a) was performed using keywords they collected in the *exploration* stage. Common keywords include materials (e.g., wooden desk, fabric sofa) or styles (e.g., ethnic rug). A3 and B3 discovered an exceptional way to use 'size' as a keyword during *exploration*, such as '800 desks' for 80cm width desks. This keyword based search was a barrier for several participants as they failed to specify their style [5, 50] and instead used adjectives such as 'warm-tone sofa' or 'cool-feeling rug.'

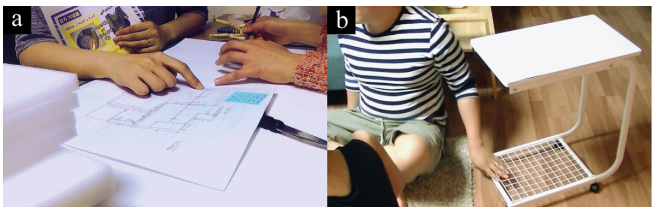

Figure 3. Prototyping activities in the Exploration stage: (a) B1 drawing a floorplan and brainstorming, and (b) C1 husband testing their existing side table to identify requirements.

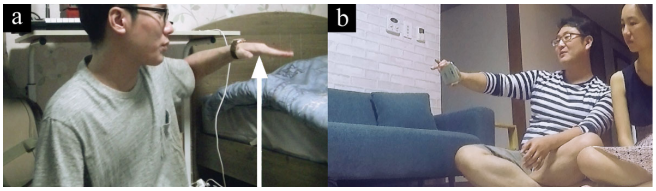

Figure 4. Prototyping activities in the Realization stage: (a) A3 estimating the appropriate height of a side table, and (b) C1 using his mobile phone with a product photo to visualize it in place.

Prototyping with their House

All households had difficulty imagining the product in use in their houses, regardless of whether they found it offline or online. Their primary need was to visualize the item in their home. To this end, C2 brought photos of their interior to the IKEA furniture mall to select a product with a similar material. During the interview, B1 showed photos she found in the online user reviews that had interiors similar to her room. C1 also found a photo of a product decorated with the same cushion as theirs. Such photos assured people that the item would look good in their house. Other participants tried to visualize the candidate item in their home. D3 asked the seller to bring leather samples for their chair, *"By comparing that sample material with our sofa leather, we selected the best one that matched our home."* Many households measured dimensions with measuring tape so that they could easily assess the position of an item. One household, C1, used his phone with a product photo as a low-tech augmented reality display to simulate the product as if it were in the room (Figure 4b).

Every household wanted to check candidate items for comfort. The easiest way to do this was to visit the offline store and test use the item directly. For example, C4, in an offline mall, sat on the chairs one by one to test how comfortable they were. From the interviews, we discovered that people who buy expensive or ergonomic furniture preferably visit offline stores to experience the products before purchase. However, as people using online malls cannot experience the product, they relied on indirect tests. C1 measured the height of the sofa they had with a retractable ruler, and then used the results to calculate the height ratio between the sofa and the target chair. Using this relative height with the pair-use item, C1 estimated the comfort. But several households indicated having trouble estimating dimensions relative to their body. C1 mentioned, *"I tried to check the usability and comfortability of this side table when it is used with this low sofa. But it is hard to figure out how."*

Getting Expert Advice from Others

Before making decisions, participants needed to gain confidence by consulting others. Several participants asked for advice from people who had expert knowledge. C3, D1 and D3 asked salespeople, who they considered to be experts due to their extended experience with customers. D1 shared their history of wallpaper selection,*"At first, we decided to cover our wall with white solid color, but the seller stopped us and told us that it is too boring. She recommended another item with a light stripe pattern, which was a bit more refined."* Some participants asked for opinions from acquaintances who knew their houses or preferences. For example, B2 mentioned during the interview, *"I would rather get an opinion from people who visit my house often, who are frequent visitors, and also the future user of the product. ... She knows my house situation very well, so I expect she can give me a useful opinion."* A2, A4 and B4 asked for feedback from friends who were in similar situations. To gain confidence on item quality, they relied on opinions from the crowd, especially when buying online. Most participants looked at user reviews and checked other users' feedback to learn what to avoid. For instance, B1 mentioned, *"When I buy things online, I always check if anyone has complained about the color of the real product compared to the picture."*

For some participants, it was hard to find furniture that fully satisfied their needs. In this case, D3 decided to upgrade their previous chair, and D4 customized the height of their new stool. Otherwise, they had to compromise among requirements. For example, B3 mentioned, *"I decided to buy a simple table without any extra shelves on it. That was the only option for a pretty desk. Otherwise, I would have had to buy an ugly desk. So I bought one extra wood shelf separately to complement the functionality."*

Usage at Home

After purchasing the items, participants start using them in their homes and routines. Three households, A3, A4 and C4, were satisfied with their purchases and mentioned in the post-purchase interview that they would prefer to buy the same one again. The other 12 households were mostly satisfied with their decisions but indicated minor problems with the item in use. One household, D4, found major problems with their stools' comfort. People who bought a cheap item as a prototype, explained how they had reflected after the first purchase iteration. A4 pointed out that he would choose the size again based on the rug they had already bought. B2 stated that she would choose a thicker one because the current one is not durable.

Most participants realized they had made errors estimating dimensions. C2, for example, believed they could select proper sized items without measuring, and visited offline stores without any numeric information. However, after placing the items in their home, they realized that the table was too big and could not use the extension function, as shown in Figure 5a. Other participants measured the available space or objects with a tape measure; however, they failed to identify the appropriate size for their bodies. D4 wife even considered ergonomic guidelines for chair heights, but her husband did not apply that properly in their design due to his lack of skill. As a result, the stool they ordered was too low for their island table.

Errors in dimensioning were often because participants used dimensions that satisfy one requirement and did not take other important usage requirements into account. These issues surfaced when they started to use the items. For example, B2 approximated the size of her rug based on her house layout. But when her friend visited and they had dinner, she realized that the rug was a bit small for two people and a table. Similarly, D1 only considered body height when installing shelves

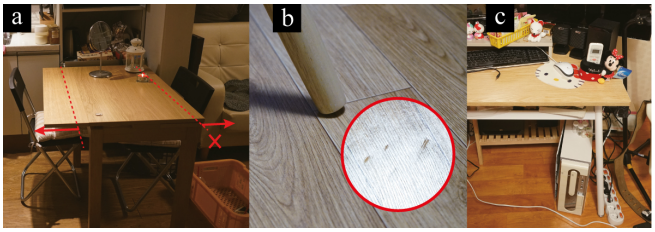

Figure 5. Usage problems found: (a) C2 bought a table too large to use the extension function, (b) C4 bought a chair which made dents and scratches on the floor, (c) B3 could not place the computer efficiently due to slanted table legs.

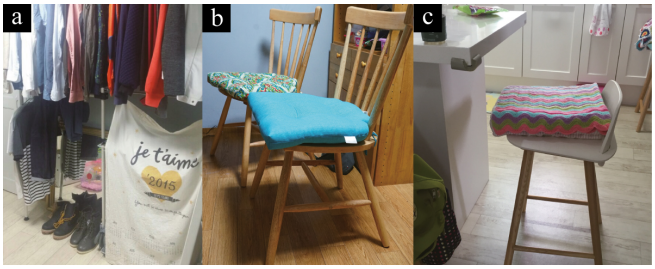

Figure 6. Appropriation of furniture to overcome problems: (a) D2 covered their clothes hanger rack with fabric, (b) C4 decorated a chair with colorful cushions, (c) D4 used a thick cushion to make the chair higher.

on the wall, but forgot that their children frequently stood on the sofa, and as a result, they often hit their heads. In some cases, we discovered that products that participants bought revealed other problems they did not expect. C4 bought their chair after carefully testing it for comfort at offline shops; however, they did not think about the leg details. After using it for a while, they found that their new chair made numerous dents and scratches on the floor, as depicted in Figure 5b.

Some participants selected products on aesthetics and found issues in the product's functionality. For example, B3 liked the design of a desk with slanted legs. However, when in use, she found that her computer didn't fit because of the leg angle, as shown in Figure 5c. In B1's case, she bought a rug to protect the floor from the dents caused by her chair, but as she focused more on the aesthetic requirements, the rug she selected turned out to be too thin, and still made marks on the floor. Some aesthetic dissatisfaction was occasionally shown from households who bought furniture from online malls without seeing the actual product. B1 was unsatisfied with the color of the wood since the color was much lighter than she expected. Also, D2 was not happy with the looks of the steel legs. But, overall, most people didn't mention significant problems with aesthetics.

Active participants tried to overcome problems by appropriation [46]. In the case of D2, she was not happy with the appearance of her choice, so she covered the clothes hanger rack with fabric (Figure 6a). C4 couple bought two wooden chairs because the husband preferred a simple combination. The wife accepted his opinion, but she decorated the chairs with colorful cushions she had bought previously (Figure 6b). D4, on the other hand, found that their chair was too low to sit. So, the wife put a thick cushion on the chair so that their daughters could comfortably eat their breakfast (Figure 6c). Some people found new and unplanned uses for their purchases. A4 did laundry and then hung his rug to dry near the main door. The next day, when he came back from school, he realized that the rug looks very pretty on the wall, and kept using it for wall decoration. Five people changed the position or layout of a product after they had used it for a while.

COLLABORATION AMONG FAMILY MEMBERS

As furniture is a shared item, all family members (in the non-single households) participated during the entire purchasing cycle. Although we conducted a study with a small number of samples, we observed two styles of collaboration during the *exploration* stage. The young couples (type C) discussed and made all decisions together during the entire process. C1 explored online images together while sitting on the sofa side by side and C4 visited offline stores together for better discussion. C4 mentioned, *"Online shopping is usually a lonely activity. However, when we go out to offline store, we discuss why I like certain items. That is one of the reasons I prefer offline exploration."* When non-co-located and direct communication was impossible, they shared the output from their individual *exploration* frequently through social messaging applications. (C2 husband, diary-*"Hey, I found one reference photo for our new dining table. Please take a look. What do you think?"*, C3 wife, diary-*"Hey, please check this website. Here, you can see various types of sofas. If you select style keywords in the right tab, the sofa images filter accordingly . If you tell me which style you like the most, I will refer to that."*) However, they had trouble in communication because it was hard to share their thoughts with words. Therefore, they used product images as a communication tool.

On the other hand, we found that households with experience in buying items, such as type D, took a different approach. A *leading designer* explored the furniture style and occasionally shared results for discussion and input from their spouse. D1 mentioned, *"I did not want to share every photo I found during my personal exploration period. If so, we might discuss too many things, and eventually fight. So I prefer having personal time for exploration, and then discuss with him with the options I come up with."* The *follower*only considered specific details such as installation or size. In our study, the role of *leading designer* was usually taken by the wife. As all four wives were not full-time workers, they had more time compared to their husbands, and more interest in interior items. But, when the primary user of the target item was the husband, he took the role of leading designer. D1 husband mentioned, *"The shelves in the study room were bought by myself, not her. I searched for various options before i finally found this item at the IKEA."*

When making decisions in the *realization* stage, all couples showed a cooperative process. When they had conflicting opinions, they started to persuade each other by describing the merits the product might have in the future. C4 wife persuaded her husband to buy a chair with a square shaped back by highlighting that she can hang her handbag on it. Eventually, all compromised and made decisions together. For

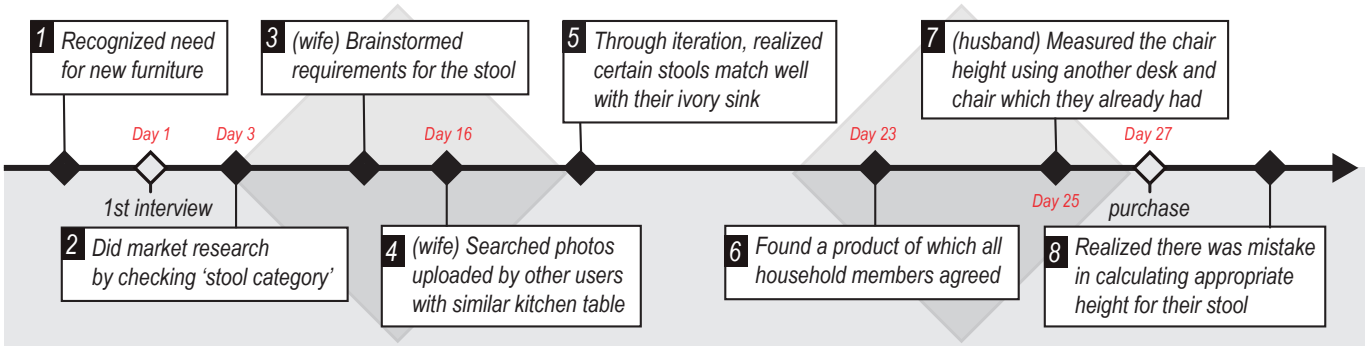

Figure 7. Journey map of family D4. They went through several stages before they purchased their stool.

example, C1 mentioned *"I like having bricks in the living room. Actually, my husband does not like antique style, but he compromised with my opinion by selecting a white brick wall."* Most of the families went through persuasion and compromise steps, except D1, who bought very cheap products to test them out. Children made little contribution to the process, only providing occasional comments on style during the final stage.

DISCUSSION

This study with 16 households provides insight into the journey that casual users make when purchasing furniture for their houses. As illustrated in Figure 7, families engage in a collaborative and iterative [35] process during which they define their requirements and taste, and gain insight into the features and use-scenarios of the items they want. We framed this purchasing journey as a design process [7]. Two distinct stages were found in the workflow: for 'understanding design requirements' and for 'prototyping solutions in their house,' which relate to the *pre-purchase search* and *evaluation of alternatives* in the EKB model [3] in consumer behavior, and the *definition* and *execution* stages in the double diamond model [7]. In this section we highlight five insights we found in the practice of acquiring and appropriating furniture items in the home and within families through the 'lens of design'. Then, we reflected on how these insights encourage the future customization and fabrication interface.

External Information Sources for Casual Users

The participants consulted a wide variety of external information sources during the process. User-generated content such as user reviews [17] or photos shared by users had a greater influence on the decision making than the vendor-supplied information as those are seen as more trustworthy and realistic. In the *exploration* stage, personal blogs and websites [2] with photos of users' real house were found to be instrumental for education and inspiration, similar to the online resources maker communities [21] use for whom the processes is the goal. To address the needs of casual users (for whom the solution is the goal), maker resources could include context-in-use information regarding the DIY object, in addition to fabrication instructions.

In contrast, in the *realization* stage, participants relied on in-depth qualitative information. They required opinions, feedback and suggestions [15] to avoid common pitfalls and usability issues. In this stage, users turned to experts such as friends or parents (for expertise in usage), salespeople and professional designers (for expertise in product features), rather than crowd knowledge. Hence, for this stage, we could think of teleoperation interfaces for experts to give in-depth advice on location.

In the *exploration* stage, the most sought information was related to styling, and participants collected large quantities of related images while developing or refining their taste. Using images proved a convenient way to materialize their ideas because they found it difficult to describe aspects of style. However, when they wanted to match the style of new items with their existing furniture or home, they were forced to verbalize these existing aspects as keywords in search engines. When casual users use fabrication interfaces to customize their items, they are likely to encounter similar issues expressing the style they want. Including images as input for style or providing automatic style suggestions, could decrease the gap between what they want and what they make.

Situated and Experiential Prototyping at Home

In the study, we found that all households use prototyping to gain understanding in their requirements and to test the fit of the furniture in their houses. We identified a wide variety of strategies. In the *exploration* stage, these activities did not include specific items, but mostly focussed on the available space and relationship with existing items. Sketching floor plans and prototyping future items with existing furniture situated in the target space helped let them explore solutions and understand the spatial impact.

However, prototyping in the *realization* stage was mostly for visualizing items in their house. Some visualized the product on a one-to-one scale with tapeline, and one held a phone with a photo to simulate the product in the room. Another participant asked the seller to bring sample materials to their home to check whether the color matches well with the other furniture. Therefore, a system that allows people to design directly in the environment would help the participants in their information need. Fabrication tools should support situated prototyping or direct visualization, such as Protopiper [1], which act as an extension of tapeline, but should also enable rapid design iterations.

We frequently observed participants face difficulties trying to estimate the future product for comfort and use using their body. After having used the item for 8 weeks, most participants indicated unanticipated usability or comfort problems. Except three households, they had bought cheap alternatives (less than $15) to try out the product in-use before making a decision. These prototyping activities show similarities to experience prototyping [6]. Research into situated modeling [22, 24] aims to support casual users to model virtual furniture in the target environment. However, as these models are virtual, providing feedback on the product *in-use* is challenging. To some extend feedback on ergonomics could be embedded in the design application similar to physical [42] or fabrication simulations. However, interactive prototyping that includes physical feedback in-use, is a challenge for the future and might involve low-cost cardboard prototypes, haptics, or shape-changing furniture.

Mobile Media in the Design Process

In contrast to earlier studies into furniture purchase [25], we found that in South Korea, all households exclusively used mobile phones in both stages. Only 3 out of 16 households occasionally used a PC or laptop to organize bookmarks or watch images on a large screen. Images collected during the information gathering were saved in online albums, even if the original, paper version was available for collection. This practice helps sharing and curating ideas or thoughts between families or friends by sending images using social network services (SNS). With consideration to C4's comment that they prefer offline-shopping as they wanted to communicate directly while seeing the same product, the mobile SNS compensates for the pitfall of online-exploration and provide effective non-co-located collaboration among stakeholders. The future fabrication tools should reflect the qualities of SNS, which are non-co-located, non-synchronous and over time.

Another reason for using mobile devices was portability and easy accessibility at any time or place. In the *exploration* stage, mobile devices were used as a medium to connect online and offline sources (e.g, bring inspirational sources from web to the living room, and bring the interior to the offline store). Future mobile fabrication interfaces should consider to situate the design practices not only in the living room, but also everywhere including friends' houses or department stores where they get inspirations.

Collaborative Process among Households

We discovered that spouses participated and collaborated in different ways. Some couples prefer exploring product aesthetics and discussing opinions in a synchronous and co-located situation. However, in other couples, one person took charge. Various factors influence the type of collaboration: whether they are moving into a new house or replacing an existing item, their familiarity with the product and whether they are the primary user or the trust level between spouses (how well they know each other). However, all final decisions were made in their house and made together through in-depth discussion. Unlike professional designers, the family members are both designers as well as users of the items. So, while they make decisions, they reminded their partners on what to consider if the partner forgets something. The single households, however, get help from other friends or parents who know their lifestyle or preferred style for making final decisions.

The type of collaboration also seems different when discussing aspects of styling or functions. As described above, people communicate mostly through images for aesthetics (e.g., expressing color by pointing at a color in a picture). In contrast, functional aspects are discussed through embodied prototyping or with use-scenarios or usage-experiences when non-co-located. When one spouse describes a preferred scenario, both of them brainstorm which product could satisfy their needs.

Although furniture is a shared product, and decision making is shared within the household, current design and fabrication tools for casual users are mostly focused on single user interaction. In order to make fabrication tools suitable for people's daily lives, interfaces should support collaboration and should be able to support process. Also, the tools should think in roles or personas, e.g. user, decision maker, stylist or evaluator. Additionally, in order to support single families, who do not have a partner, to help make good decisions, a collaborative virtual partner could be considered.

Temporality in Design

We observed design conflicts in terms of temporality [12] when designing both for their current reality and their future situation. Families with children expected to use the new purchase for about 9 years, but for other household types this was less than 3 years. Single households lowered the priority of aesthetic aspects and tried to select cheap solutions within the boundary of requirements, as they plan to throw it away when moving out. In contrast, families tend to take into account temporal qualities and also their future home and family situation while selecting furniture. For instance, the family who bought cushions for their uncomfortable sofa actually intended the sofa as a bed for their future offspring in their next apartment. This exemplifies the complexity of the process of purchasing furniture.

LIMITATIONS AND FUTURE WORK

In our study, participants bought various types of items, with various types of motivations. Although a broad understanding of the design workflow was possible from this variety, it is necessary to focus on one type of product or motivation for in-depth analysis. In addition, our study was conducted with only 16 middle-income households living in South Korea. However, in order to avoid cultural issues regarding houses, such as sedentary lifestyle or impact of DIY furniture, the study should also be conducted with people in western cultures. Also, the practices of design might be different for other types of product, such as non-durable, small, wearable items, so further investigation on other item categories should be performed.

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